VITISKILLS

E-BOOK FOR VINEYARD WORKERS

INNOVELA SRL

The VITISKILLS consortium

Introduction

In response to the changing agricultural practices, as well as the increasing effects of climate change in viticulture, project VITISKILLS is aiming to address the needs of vineyard workers through the creation of an open, online course providing them with green and digital skills aiming to lead to sustainable viticulture becoming the norm throughout the European Union.

This e-book is based on the VITISKILLS curriculum which was developed based on the evidence stemming from needs assessment, research on analysis of challenges and work requirements in viticulture, focus group with experts in the field and survey results with vineyard workers, farming and wine associations, and field experts.

Its goal is to provide a brief, comprehensive view of the course developed by the VITISKILLS consortium and specifically partners involved directly in the field of viticulture, namely ARIS (Italy), LAUNIO (Spain), QUERCUS (Portugal). The course is aimed at vineyard workers who wish to extend their knowledge in the field of sustainable viticulture as well as increase the production and quality of their vineyards.

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Chapter 1
Regenerative Viticulture

Core principles of regenerative viticulture

Biodiversity: includes providing habitat for wildlife that aid in pollination and pest management, such as beneficial insects, birds, and other animals. Promote biodiversity by creating hedgerows, growing native cover crops, and protecting nearby or inside vineyards natural habitats.

Soil Health: The establishment and maintenance of wholesome soils are given priority, and replace the use of synthetic fertilizers, pesticides, and herbicides with organic and natural methods like cover crops, composting, and crop rotation should be employed to increase soil fertility and structure over the long term.

Water and Energy Management: In order to meet the needs of the vines while using less water, drip irrigation, soil moisture monitoring, and water-saving techniques are used. The water management approach might also incorporate wastewater recycling and rainwater collection. Utilizing irrigation technology also lowers energy costs in the vineyard, minimizes negative environmental effects, and prevents excessive carbon emissions. On the other hand, the winemaking processes at the winery are where the most effective energy management measures are used.

Carbon Sequestration: Using the oldest and most effective technology available, plant life and photosynthesis together with no-till or reduced-tillage practices, preserving permanent vegetation, and growing cover crops can all help to create soil organic matter and retain carbon.

Integrated Pest Management (IPM): In order to control pest populations, IPM strategies other than synthetic pesticides are used, such as pest monitoring, the use of natural predators, pheromone disruption techniques, and other biological management techniques.

Considerations for the Community and Society: In regenerative viticulture, it is acknowledged that there is a need to interact with local people and take social issues into account. Fair labor practices, intercommunal harmony, and support for regional economy are a few examples of this.

How to start with Regenerative Agriculture

By tiling, farmers turn the soil to improve air and water infiltration so that seeds and roots can thrive. Additionally, the procedure allows fertilizer to penetrate the soil more effectively and prevents the growth of weeds. But there is an issue. Over time, tilling makes the soil less useable because it makes it easier for the soil to lose water, minerals, and microbial populations. One of the key reasons for desertification is this. By not tilling more water and minerals are held in the soil on farming. Additionally, it improves the microbial variety in the soil when cover crops are also used. All these elements maintain the soil's long-term reusability and keep the crops more nutrient-dense.

Cover crops function in a way that makes it appear as though the primary crop is being assisted by its very own helper crops. These support crops provide weed and insect control as well as soil health maintenance. They serve as crop guardians in a sense. Along with the primary crop, which will be sold for a profit, a cover crop is sown. A cover crop can enhance the health of the soil, prevent weeds and other organisms from attacking and devouring the main crop, and increase the variety of living things on the farm rather than being there only to be sold.

Numerous farmers today utilize **pesticides and synthetic fertilizers**. But when combined, cover crops, livestock integration, and no-till farming offer sustained pest prevention and organic fertilizer without endangering human or environmental health.

What if crops **and farm animals** could live side by side on the same farm? It turns out that this notion, which is as old as agriculture itself, could benefit world agriculture in a variety of ways. In this scenario, a mutually beneficial relationship between crops and animals is possible. The animals' manure helps the soil get healthier as they eat extra crops or certain cover crops. In reality, it has been discovered that introducing cattle to agricultural land can speed up plant regeneration, improve nutrient density, and boost microbial communities in the soil. Animals also aid in preventing pests from creating habitats on farms by feeding from the land when crops are dormant. Weeds are naturally eliminated by these animals as well.

Biodiversity Protection

Livestock can contribute to biodiversity conservation and ecosystem health in the most rewarding way; however, it typically takes more time and effort to put this practice into action. Following are some of the benefits of have livestock in the vineyard:

Grazing Management: Livestock, such as sheep, goats, or cattle, can be used for targeted grazing in vineyards. Grazing density, timing, and rotation schemes through different sections of the vineyard, can help control vegetation, manage cover crops, and reduce weed growth. This targeted grazing minimizes the need for herbicides or mechanical intervention, while also promoting the growth of diverse plant species. Following the grazing of bigger livestock, farmers have the option to introduce poultry to feed on the insects that are attracted by the fresh manure.

Nutrient Cycling: Livestock grazing improves nutrient cycling in vineyard ecosystems by providing manure, improving soil fertility, and supporting plant growth.

Soil Health Improvement: soil health is improved by promoting plant material breakdown, microbial activity, and nutrient cycling, enhancing soil structure, moisture retention, and fertility.

Habitat Creation: Livestock integration in vineyards supports biodiversity by creating diverse habitats, supporting insects, birds, and mammals, and preventing habitat fragmentation through rotational grazing.

Pollinator Support: Livestock grazing supports pollinators by promoting diverse flowering plants in vineyards, providing food sources and enhancing their abundance.

Genetic Diversity: Livestock grazing preserves local breeds, supports regenerative viticulture, and conserves heritage breeds through genetic diversity.

Soil Management

- **Soil Health Assessment:** It's crucial to evaluate the condition of the soil before beginning any soil management procedures. This may entail testing the soil to evaluate its pH, organic matter content, and nutrient levels. It is also crucial to evaluate the water-holding capacity, compaction, and soil structure.
- **Cover Cropping:** In regenerative viticulture, cover crops are frequently planted in the spaces between grape rows. When absorbed into the soil, cover crops like legumes, grasses, and clovers help reduce erosion, enhance soil structure, control weed growth, and supply organic matter. They also encourage nutrient cycling and advantageous microbial activity.
- **Composting and Organic Matter:** Composting the soil is a practical approach to increase the organic matter and fertility of the soil. Composting winery waste, prunings from vineyards, and other organic materials can result in a soil amendment that is rich in nutrients. Organic matter improves soil structure, maintains beneficial soil organisms, and aids in moisture retention.(Paradelo et al., 2011)
- **Minimal Tillage:** Minimizing or avoiding tillage is a key principle of regenerative viticulture. Tilling can disrupt soil structure, accelerate erosion and evaporation, and deplete soil organic matter. No-till or reduced tillage practices help preserve soil structure, promote the growth of beneficial soil organisms, and minimize carbon loss from the soil.(Hudson, 1987)

Soil Management

- **Soil Amendments:** Instead of relying solely on synthetic fertilizers, regenerative viticulture emphasizes the use of natural soil amendments. These can include mineral-based amendments like rock dust, which provide micronutrients, and biofertilizers derived from compost teas, vermicompost, biochar, or beneficial microbial inoculants that enhance soil biology such as biodynamic preparations. (Giagnoni et al., 2019; Schmidt et al., 2014)
- **Mulching:** Mulching vineyard rows with organic materials, such as straw, wood chips, or grape pomace, can help conserve soil moisture, suppress weeds, and improve soil health. Mulch acts as a protective layer, reducing soil erosion and maintaining more stable soil temperatures. (Čížková et al., 2021)
- **Microbial Activity and Soil Biology:** Regenerative viticulture recognizes the importance of soil microbial activity and biodiversity. Encouraging beneficial soil organisms like mycorrhizal fungi, earthworms, and beneficial bacteria through organic practices helps improve nutrient cycling, disease suppression, and overall soil health. (Njira & Nabwami, 2013)
- **Precision Irrigation:** Efficient water management is crucial for both vine health and soil conservation. Adopting precision irrigation techniques such as drip irrigation or soil moisture sensors ensures that water is applied precisely where and when needed, minimizing water waste and reducing the risk of over- irrigation.(Kamienski et al., 2019)

Pest Management

- **Integrated Pest Management (IPM):**

IPM Approach: careful consideration of all available plant protection methods and subsequent integration of appropriate measures that discourage the development of populations of harmful organisms and keep the use of plant protection products and other forms of intervention to levels that are economically and ecologically justified and reduce or minimize risks to human health and the environment. 'Integrated pest management' emphasizes the growth of a healthy crop with the least possible disruption to agro-ecosystems and encourages natural pest control mechanisms This includes legislative, cultural, biological, biotechnical, physical, and chemical control methods.(Ciancio & Mukerji, 2007; European Commission et al., 2023)

Pest Monitoring: Regularly monitor vineyards for pest populations, using techniques such as visual inspection, pheromone traps, or remote sensing technologies. Early detection helps determine the appropriate timing and intensity of pest control measures, allowing for the use of less aggressive measures.(Cavaco et al., 2005)

Thresholds and Action Plans: Establish action plans regarding economic-injury levels (EIL) while developing multitool action plans that outline appropriate management strategies when EIL raises above a determined threshold.(Cavaco et al., 2005)

Pest Management

- **Cultural Practices**

Vineyard Sanitation: Many pathogens, both bacteria, virus, fungi, and pests, can survive over winter in the soil and in rotting wood. Keep vineyards clean and free from debris, including diseased wood from the previous season and rotting fruit. If mulching is practiced, the farmer must make sure to breakdown the pruning material as to speed up the degradation.(Cooke et al., 2009)

Canopy Management: Proper canopy management techniques, such as adequate pruning and trellising or tutoring can promote airflow and sunlight penetration, reducing the conditions favorable for pest and disease development.(Silva et al., 2011)

Crop Rotation and Diversity: Rotate grapevines, plant cover crops, disrupt pest cycles, promote biodiversity, attract beneficial insects.

Soil Health: aiming for a so-called suppressive soil, benefits plant growth and natural pest resistance through cover cropping, composting, and organic amendments.

- **Biological Control**

Beneficial Insects: Encourage the presence of beneficial insects, such as ladybugs, lacewings, and predatory mites, which can naturally control pest populations. Provide habitat and food sources for these beneficial insects through the planting of flowering plants and maintaining native vegetation.

Biological Control Agents: Introduce or conserve natural enemies of pests, including parasitic wasps, predatory insects, and nematodes, which can help control pest populations without the need for synthetic pesticides.

Pest Management

- **Physical and Mechanical Control**

Traps and Barriers: Utilize mechanical traps and physical barriers to capture and monitor pests in grape clusters.
Mechanical Removal: Handpicking, vibration, pruning infected vines to eliminate pests.
Vineyard Design: Optimize vineyard design and layout for effective pest management, minimizing development and avoiding wet spots.

- **Organic and Low-Impact Pesticides:**

Selective Pesticides: Select low-impact pesticides for pest control without harming beneficial organisms.
Organic Certification: Follow organic farming practices and seek organic certification, which emphasizes the use of natural and non-synthetic agrochemical products. (Félix & Cavaco, 2009)

Organic & Biodynamic Vine Growing

To achieve organic & biodynamic vine growing, organic farming must follow some key principles, such as adequate conception and management of the biological processes based on natural resources from ecological systems that:

1. Deploy and use living organism and mechanical production methods;

2. Practice sustainable agriculture and aquaculture to utilize soil and fisheries' resources in a sustainable manner.

3. Exclude the use of Genetically Modified Organisms (GMO) and products obtained from or through the use of GMOs, with the exception of animal pharmaceuticals.

4. Include crop rotation;

5. Include cultivation of nitrogen fixing plants and other green manure crops to restore the fertility of the soil;

6. Prohibition of use of mineral nitrogen fertilizers;

7. Reduce the impact of weeds and pests, organic farmers choose resistant varieties and breeds and techniques encouraging natural pest control;

8. Encourage the natural immunological defense of animals;

9. Maintain animal welfare and health, organic producers need to prevent overstocking.

Chapter 2

Viticulture 4.0

Smart irrigation

Smart Irrigation: Smart irrigation systems estimate and measure diminution of existing plant moisture in order to operate an irrigation system, restoring water as needed while minimizing excess water use. (Darshna et al., 2015)

These technologies help vine growers to monitor soil moisture levels, weather conditions, and plant water requirements in real-time. Some features of smart irrigation systems include:

A. **Soil Moisture Sensors:** These sensors are placed in the vineyard soil to measure moisture levels accurately. They provide data on when and how much water should be applied, preventing over- or under-irrigation.

B. **Weather Stations:** Weather stations collect data on temperature, humidity, wind speed, and solar radiation. This information is used to adjust irrigation schedules and optimize water application based on current and forecasted weather conditions.

C. **Automated Irrigation Controllers:** These controllers receive input from soil moisture sensors and weather stations, enabling automated irrigation scheduling. They can be programmed to adjust irrigation based on specific vineyard needs, reducing water waste.

Fertilisers distribution

Fertilizer Distribution: Efficient distribution of fertilizers is crucial for vine health and productivity. Advancements in technology have led to improved methods of fertilizer application. Some notable techniques include:

A. **Precision Sprayers:** These sprayers use targeted nozzles or sprayer heads to deliver fertilizers directly to the vine's root zone. By precisely controlling the spray pattern and volume, the distribution is optimized, minimizing waste and ensuring proper nutrient uptake.

B. **Variable Rate Technology (VRT):** VRT systems analyze soil nutrient levels and apply fertilizers at varying rates based on specific vineyard requirements. This technology allows growers to customize nutrient application across different areas of the vineyard, optimizing fertilizer usage and plant nutrition.

C. **Controlled-Release Fertilizers:** These fertilizers are designed to release nutrients gradually over an extended period. They provide a consistent and steady supply of nutrients to the vines, reducing the risk of over-fertilization and minimizing environmental impact.

Dosing/Nutrition solutions

Dosing/Nutrition Solutions: Accurate dosing of nutrients is vital for vine health and the development of quality grapes. Several technologies and solutions facilitate precise dosing and nutrition management:

A. **Nutrient Monitoring Systems:** These systems measure key nutrient levels in the soil or plant tissues and provide real-time data to growers. Based on the analysis, growers can adjust fertilizer dosing and optimize nutrient balances to meet the vines' specific needs.

B. **Drip Irrigation Systems:** Drip irrigation delivers water and nutrients directly to the vine's root zone. By combining water and nutrient supply, growers can precisely control the dosage and ensure efficient uptake by the plants.

C. **Nutrient Formulations:** Advanced nutrient formulations, such as liquid concentrates or soluble powders, allow for precise dosing and easy application. These formulations often provide a balanced mix of essential nutrients tailored to the vine's growth stages.

Smart Monitoring Technologies

Geolocation: Georeferencing is the process of establishing the relationship between spatial information and its geographical position. This makes a comparison possible among the different spatial data detected in the vineyard, such as soil physical properties, yield, and water or fertilizer contents. (Vieri et al., 2012)

In viticulture, geolocation systems are used to precisely track and map vineyard boundaries, rows, and individual plants. This information helps vineyard owners manage their vineyards more effectively by monitoring plant health, applying treatments accurately, and optimizing irrigation and fertilization practices.

Remote Sensing: Remote sensing techniques rapidly provide a description of grapevine shape, size, and vigor and allow assessment of the variability within the vineyard. This is image acquisition at a distance with different scales of resolution, able to describe the vineyard by detecting and recording sunlight reflected from the surface of objects on the ground. (Hall et al., 2022)

In viticulture, remote sensing technologies, such as drones or unmanned aerial vehicles (UAVs), are used to capture high-resolution images of vineyards. These images provide detailed information about the health and vigor of the grapevines, allowing growers to identify potential issues like nutrient deficiencies, disease outbreaks, or water stress. By analyzing the remote sensing data, vineyard managers can target specific areas for interventions and optimize resource allocation.

Smart Monitoring Technologies

Satellite Imagery: Satellites have been used in precision farming for over 40 years, when Landsat 1 was launched into orbit in 1972. It was equipped with a multispectral sensor and provided a spatial resolution of 80 m per pixel with revisit intervals of approximately 18 days. Landsat 5 was launched in 1984 and collected imagery in the blue, green, red, near-infrared, and thermal bands at a spatial resolution of 30 m. The first application of remote sensing in precision agriculture occurred when Landsat imagery of bare soil was used to estimate spatial patterns in soil organic matter content. (Mulla et al., 2013)

Satellite imagery provides a broader perspective of vineyards and can cover large areas. Satellites equipped with advanced sensors capture images of vineyards from space at regular intervals. This imagery helps viticulturists monitor the overall health of vineyards on a larger scale, assess vineyard variability, and detect any potential issues affecting multiple areas. Satellite imagery can also be used to analyze the impact of environmental factors such as temperature, precipitation, and sunlight on grapevine growth and development.

By combining geolocation, remote sensing, and satellite imagery, viticulturists can gain a comprehensive understanding of their vineyards and make data-driven decisions. These technologies enable them to monitor and manage vineyard conditions in real-time, detect problems early on, and implement precise interventions, resulting in improved grape quality, increased yields, and enhanced sustainability in viticulture practices.

Biosensor Technologies for pathogen detection

1. Enzyme-Linked Immunosorbent Assay (ELISA): ELISA is a biochemical assay that uses antibodies and an enzyme-mediated color change to detect the presence of either antigen (proteins, peptides, hormones, etc.) or antibody in a given sample. (Stephanie, D. & Kruti, R., 2013)

It involves immobilizing specific antibodies on a solid surface and then detecting the presence of pathogens by binding them with corresponding antibodies. ELISA can be used to detect a wide range of grapevine pathogens, including fungi, bacteria, and viruses.

2. Polymerase Chain Reaction (PCR): PCR is a simple, yet elegant, enzymatic assay, which allows for the amplification of a specific DNA fragment from a complex pool of DNA. (Mullis, 1990)

PCR is a molecular technique that amplifies specific DNA sequences, allowing for the detection of pathogens with high sensitivity and specificity. PCR-based biosensors are commonly used in viticulture to identify and quantify pathogens like phytoplasmas, bacteria, and viruses. Real-time PCR (qPCR) is particularly useful for rapid and accurate pathogen detection.

3. Immunochromatographic Lateral Flow Assays: By Gaiping et al. (2009) The immunochromatographic lateral flow strip test is a one-step test that facilitates low-cost, rapid identification of various analytes. Lateral flow assays are simple and rapid biosensors that use antibodies to detect pathogens. They are similar to pregnancy test kits and can provide on-site detection within minutes. Lateral flow assays are valuable tools for quick screening of pathogens in the field, providing growers with immediate results for timely disease management decisions.

Biosensor Technologies for pathogen detection

4. **Surface Plasmon Resonance (SPR):** It was suggested a few years ago that SPR in thin metal films on dielectric (glass) supports could be used for biosensing purposes (Lieberg et al. 1983). SPR has now been developed into a very versatile method for the analysis of biospecific interactions, such as that between antigen and antibodies. (Löfås et al. 1991)

   SPR biosensors detect changes in refractive index on a sensor surface when a target pathogen binds to specific antibodies. This technology offers label-free, real-time detection and is highly sensitive. SPR can be used for the detection of various grapevine pathogens, including bacteria and viruses.

5. **Microfluidic-based Biosensors:** Biosensors combine a molecular recognition element with a signal conversion unit (Mohanty and Kougianos, 2006). Some biosensors have been successfully commercialized for clinical applications such as electrochemical blood glucose sensors (Kissinger, 2005). Molecular biosensors are more preferred as a clinical diagnostic tool than other methods partially because of real-time measurement, rapid diagnosis, multi-target analyses, automation, and reduced costs (Luong et al. 2008)

Characterization and detection of grapevine diseases

- **Symptom identification:** Grapevine diseases can exhibit various symptoms that can be visual, physiological, or both. Common symptoms include discoloration of leaves, wilting, deformities, necrosis, and abnormal growth patterns. It's important to carefully observe and document the specific symptoms exhibited by the grapevines.
- **Disease classification:** Grapevine diseases can be caused by various factors, including fungi, bacteria, viruses, and environmental stressors. Understanding the potential causes of the observed symptoms helps in narrowing down the possible diseases.
- **Sample collection:** To accurately diagnose grapevine diseases, it is necessary to collect plant samples for laboratory analysis. This typically involves obtaining leaf samples, canes, or clusters showing visible symptoms. Care should be taken to collect samples from both affected and healthy parts of the vineyard for comparison.
- **Laboratory analysis:** Once the samples are collected, they are sent to a specialized laboratory for analysis. Various techniques can be employed, including microscopic examination, culture-based isolation, DNA-based techniques (such as polymerase chain reaction, PCR), and serological tests.

Characterization and detection of grapevine diseases

- **Disease detection:** Based on the laboratory analysis, the specific grapevine disease can be identified. The results help determine the appropriate course of action for disease management and prevention. Some common grapevine diseases include powdery mildew, downy mildew, botrytis bunch rot, grapevine leafroll disease, and grapevine fanleaf virus.
- **Disease management:** Once the disease is identified, specific management strategies can be implemented. This may include cultural practices, such as pruning infected vines, removing infected plant material, and improving vineyard sanitation. In some cases, chemical treatments may be recommended, such as fungicides or bactericides, to control the spread of diseases.
- **Preventive measures:** Preventing grapevine diseases is crucial for maintaining vineyard health. This involves implementing strategies like regular scouting for symptoms, proper sanitation practices, using disease-resistant grapevine varieties, and optimizing vineyard management practices such as irrigation and nutrient management.

Phytosanitary products and application machinery

1. Phytosanitary Products:

a. **Insecticides:** These products are used to control and eliminate insect pests that can damage grapevines, such as grapevine moth, leafhoppers, and aphids.

b. **Fungicides:** Fungal diseases, such as powdery mildew, downy mildew, and botrytis, can affect grapevines. Fungicides help prevent and manage these diseases.

c. **Herbicides:** Weeds compete with grapevines for nutrients, water, and sunlight. Herbicides are used to control and suppress weeds, ensuring the grapevines receive optimal growing conditions.

d. **Bactericides:** Certain bacterial diseases, like crown gall, can infect grapevines. Bactericides are used to manage and prevent these bacterial infections.

e. **Nematicides:** Nematodes are microscopic worms that can damage grapevine roots. Nematicides are applied to control nematode populations and minimize root damage.

2. Application Machinery:

a. **Tractor-Mounted Sprayers:** These sprayers are commonly used in vineyards and can be mounted on tractors. They have a tank for holding the phytosanitary products, nozzles for spraying, and a pumping system powered by the tractor's engine. They are versatile and suitable for both small and large vineyards.

b. **Airblast Sprayers:** These sprayers use a high-powered fan to create an air stream that carries the phytosanitary products. The airblast sprayers effectively distribute the products over the vine canopy, reaching the leaves, stems, and fruit clusters. They are particularly useful for larger vineyards.

c. **Handheld Sprayers:** For smaller vineyards or precise spot treatments, handheld sprayers may be used. These sprayers are carried by workers, allowing them to target specific areas or vines that require treatment.

d. **Mist Blowers:** Mist blowers produce a fine mist of phytosanitary products, which is then blown onto the grapevines. They are often used in larger vineyards where a significant area needs to be covered quickly.

Chapter 3

Viticultural Data Management

Data Management Software

Agriculture-related software has been developed for a while, and there is now a wide range of options available. This set of tools includes GPS (global positioning system), distant and proximal sensing technologies, GIS (Geographic Information Systems) variations (ArcGIS, QGIS), geostatistics, AI (artificial intelligence), and DSS (Decision support systems). With so many technological advancements this can become a daunting venture that can either help or hinder any farmer who wants to go digital, as the appropriate decision meet the needs, while an incorrect one will incur at a minimum time and financial costs. One must be aware of the many types of software, potential applications, and function to make the best decision, and cost (software and hardware).

Wine grape production systems can use non-invasive sensing technologies including spectroscopy, MSI (multispectral imaging), HIS (hyperspectral imaging), and CV (computer vision) to gather vital data on the plants and land. The way growers obtain this information has changed thanks to smartphones and applications (more information on section 3.2.4 Smartphone use in E-Agriculture) and in the future, chores in the vineyard are probably going to be automated. (Tardaguila et al., 2021)

Data collection, analysis, processing and visualization

Sectors that can benefit through the use of data management software in the field of agriculture:

- Data Collection
- Data Analysis and Processing
- Data Visualisation
- Smartphone use in Agriculture

Data drawn from data management software can also improve production in the following areas:

- Canopy
- Soil
- Fruit quality

Decision Support Systems

An agricultural decision support system (ADSS) is a human-computer system that helps farmers make decisions using data from various sources. Successful examples include the Watson Decision Platform for Agriculture, which combines AI, IoT, and cloud computing to analyse crop factors. Some digital farming systems use computer vision, AI, and cloud computing to improve yield production and productivity. However, ADSSs face limitations due to lack of experience, user- friendly interfaces, and developers overlooking end-user requirements. To better apply ADSSs in Agriculture 4.0, it is crucial to analyse the requirements of Industry 4.0, which focuses on increasing productivity, allocating resources, adapting to climate change, and avoiding food waste. To address these challenges, thirteen ADSSs are selected from current literatures and a systematic literature review technique is used to detect upcoming challenges. (Zhai et al., 2020)

Many DSSs are designed to support precision agriculture (PA), which aims to optimize resources and increase the number of correct decisions per unit area of land per unit time with associated net benefits. However, models remain unfriendly and can lead to trust issues. The increasing use of farm sensors, high-tech harvesters, and drones has created a massive amount of data that may be difficult for decision-makers to grasp. Visualization is a powerful technique to address these issues and is useful in PA to communicate uncertainty from both data and models.

Visualizations can assist users in better interacting and understanding data by aggregating, filtering, searching, or sifting through relevant information. They can also offer short-term or long-term memory aids to reduce memory and cognitive load, making data more easily consumable. Participatory DSS development, where the farmer's perspective is the central focus, is essential for supporting complex data analysis by providing diverse visualization techniques and adapting the tool according to farmer needs. A comprehensive analysis of visualizations and visual analytics tools in agriculture is yet to be done, but a comprehensive analysis of their application areas, techniques, and intended end-users is needed.(Gutiérrez et al., 2019)

Prediction models

High-resolution agri-data sets, such as spatial canopy velocity and apparent soil electrical conductivity (ECa) data, are available to vineyard managers but not widely adopted commercially. These data help build systems for zonal management and link to production attributes, such as grape yield and quality. However, vine size information at veraison is too late in the season for operations that significantly alter crop load via canopy thinning. To make effective operational decision-making in-season, producers require information earlier in the season, especially in warm to hot climates. The biennial fruiting effect in Vitis sp. is crucial in systems with limiting production drivers, and growers need information on fruit set, vine size, and spatial variability. The rise in machine-learning algorithms could provide insight into using new spatial agri-data to improve operational decision-making in vineyards.

Zhai et al., (2020) reviewed ADSSs for agricultural applications, including mission planning, water resources management, climate change adaptation, and food waste control. From this study seven types of DSS that supported prediction models depending were highlighted as the best reviewed, as follows. These can serve as basis for understanding how DSS have been evolving in the last years.

Prediction models based on function:

- **Soil properties and weather prediction**
- **Crop yield prediction**
- **Machine-learning algorithms**
- **Disease and pest detection**
- **Irrigation**
- **Phenology**
- **Intelligent harvesting**

Intelligent methods for application of Plant Protection Products

Modern agriculture production uses plant protection products (PPP) to eliminate diseases, fungi, insects, and weeds. Spraying techniques like sprayers, air blasters, and foggers are simple, reliable, and low-cost. However, the spray plume generated by fans can cause spray drift, leading to large losses to the atmosphere and ground saturation. To address these issues, selective and precise PPP application is needed. Traditional dose expression models may result in excessive dosages, but the tree row volume-TRV dosing concept can be used to adjust PPP doses based on orchard structure.

The Natural Defence Mechanisms (NDM) concept aims to control key pathogens in agrocenosis by transforming the concept of plant protection. The NDM concept focuses on activating plants' defense mechanisms to be prepared for potential attacks, considering their phenological phases. Infected plants are attacked by specific, symptomatically defined noxious agents, and extracted antibodies are chemically specified and biologically determined through intracellular transducers. These signals activate the plant's immune system at multiple levels, such as production of PR proteins, enzymes, phytoalexins, salicylic acid, and ethylene. The final product, NDM, is a copy of the natural atomic matrix specific to each pathogen. NDM substances are messengers of plant antibodies, acting as a "vaccine" activating the plant's immune system, making it initially sensitive to a pathogen resistant. The application modus of NDM substances may vary among individual winegrowing regions, and the correct choice of application method must consider factors like agronomic specifics, water availability, spraying technique, and local farming practices. This approach represents the application of new technology in viticulture, developing products with zero residues, targeted activation of immune pathways, zero health risks for workers, and zero environmental burdens. (Gabel, 2019)

Chapter 4

Fostering Fair and Enabling Working Conditions

Labour Law and workers' rights

Key Employment Issues

- **Service occupancies:** Employees that need to reside on-site will most likely require a service occupancy for their accommodations. A service occupancy, rather than a lease, grants an employee a personal licence to occupy the property for the duration of their employment with the employer. Be aware that the threshold for a service occupancy is quite high: the occupation must either be essential to the performance of the employee's duties, or (if not essential), the employment contract must expressly require the employee to live on the property in order to perform their duties more effectively. It is usually advisable to clearly state it in the contract. It is critical to evaluate this issue carefully since, unless the prerequisites for a service occupation are completed, an occupier will have a tenancy (a lease) rather than a licence. A tenancy gives the employee additional rights, including eviction rights, and agricultural laborers will have more protection than a tenant in an assured shorthold tenancy ("AST").

- **Immigration:** ensure that personnel have the right to work in accordance with visa and immigration rules.

- **Employer obligations:** Employer requirements include maintaining a solid payroll process, providing accurate papers to employees (including obligatory policies), and complying with auto-enrolment pension obligations.

Vineyard owners and employers in the viticulture business should be aware with the labor laws and regulations in their different jurisdictions. They should ensure that these rules are followed in order to preserve their employees' rights and promote a positive and ethical work environment in the vineyard.

Health & Safety Standards

It is important to know your role and responsibility in a winery or a vineyard. There are three kinds of responsibilities in this sector:

- **The employers**
- **The supervisors**
- **The workers**

If you are an **employer**, these are some your responsibilities:

- Minimize hazardous workplace conditions.
- Provide your employees with education, supervision, and training specifically for your workplace.
- Set up an occupational health and safety program.
- Inform workers about any remaining hazards.
- Ensure that your employees comply with the requirements of the Regulation.
- Ensure that your workers understand their rights and responsibilities under the Regulation and that they comply with them.
- Provide copies of the Occupational Health and Safety Regulations to workers.
- Provide and maintain personal protective equipment, including clothing. Ensure that employees use them.

Health & Safety Standards

If you are a **supervisor**, these are some your responsibilities:

- Maintain the health and safety of workers under your direct supervision.
- Understand the Regulation's requirements for the work you supervise.
- Inform workers about workplace dangers and ensure compliance with the Regulation.

If you are a **worker**, these are some your responsibilities:

- Take reasonable care to protect your health and safety, as well as others who may be harmed by your actions.
- Comply with the Regulation and other legal obligations.
- Follow the approved safe work procedures.
- Avoid horseplay or similar behavior that could damage you or others.
- Do not work if you are impaired by drugs or alcohol.
- Report any accidents or problems to your supervisor.
- Use required PPE (personal protective equipment)

Most wineries are classified as moderate-risk workplaces. It is essential that you fulfill these safety requirements:

- Ensure that every worker knows where first aid kits are located and how to call the first aid attendant
- Post signs in your workplace indicating how to access first aid
- Ensure that enough workers are trained for the first aid responsibility.

People Management & Development

As a winery manager, you are in charge of supervising the whole business.
Your responsibilities include managing wine grape development, wine-tasting tours, boosting income, improving visitor experience, developing strategic plans and choices, knowing various grape processing procedures, and deciding the ideal time to harvest.
To be a successful team leader in this position, you must go beyond simply being a winemaker. Building trust among your team members is critical for establishing an open channel of communication. Every guest should have a great tasting room experience. Maintaining healthy vines through irrigation management, disease and insect control, and pruning has a significant influence on wine quality.

A vineyard manager's grasp of their guests complements their expertise of wines. It's critical to understand each guest's preferences, tastes, and overall satisfaction level. With this information, a unique and memorable experience may be tailored directly to them. Creating thorough client profiles for your vineyard involves more than simply knowing names and faces. It entails learning what each guest prefers. This useful information allows you to personalize their experience, recommend wines they'll appreciate, and increase their pleasure, perhaps leading to them spending more and becoming loyal customers over time.

The function of managing a winery is similar to that of conducting an orchestra; it demands a strong leader who can direct each component toward a flawless and beautiful performance. This includes leading the team, making critical choices, and driving the winery to success.

On the other hand, aside from academic education, professional training is essential for the growth of a winery manager. These specialist classes are vital for honing certain skills and staying current on industry trends and best practices.

Whether it's learning about current viticulture practices or understanding the complexities of wine marketing, professional training may help you prosper in this competitive sector.

Change Management & Communication

Five simple steps to create an efficient change management plan:

1. Establish clear, measurable objectives for the change management process, tied to the expected benefits of winery management software and providing a means of tracking progress and success. These objectives could include reducing manual data entry errors, decreasing production lead times, or increasing operational efficiency.
2. Identify all stakeholders affected by the change, including employees, management, and vendors, and their roles in the process. Understanding their roles and responsibilities can help address concerns and ensure active participation in the change management process, ultimately leading to a more effective outcome.
3. A communication plan should outline methods, frequency, and content for stakeholders, including regular updates on implementation progress and opportunities for questions and feedback. Various channels, such as email updates, town hall meetings, or an internal change management website, can be used.
4. Create a customized training program for stakeholders to learn new processes and technology in the winery, considering their skill sets and software requirements. This program can be delivered through workshops, e-learning modules, or mentored on-the-job training.
5. Create a comprehensive support structure for employees and stakeholders during and after the transition, such as establishing a technical helpdesk or assigning change management champions. This structure can enhance employee satisfaction and boost the chances of successful implementation.

Health and environmental risks

Viticulture, a crucial aspect of agriculture, contributes around 40% to wine's carbon footprint. To reduce this, many farmers are adopting regenerative agriculture, cover crops, renewable energy sources, and using alternative rootstock, heat-resistant grape varieties, and longer ripening grape varieties. The majority of wine's carbon footprint, 40-50%, is due to transport and packaging in glass bottles, with the adoption of boxed and canned wine growing globally. This is in response to the growing environmental concerns and the growing popularity of wine in various forms.

The risk is not only environmental. On the other hand, wine industry workers face various health risks, including musculoskeletal problems, allergic diseases, and exposure to pesticides. Viticulture workers may suffer wrist and hand injuries from vine pruning work, while wine production workers face confined spaces with low oxygen and high carbon dioxide levels, which can lead to death. Winemakers and tasters may suffer from dental erosions and sensitivity due to the acidic nature of wines they need to taste frequently. While work-related injuries are more common in the wine industry, physicians should be aware of the occupational health risks faced by these individuals, as they may be more affected by these issues than work-related diseases.

Winemaking is also a very labor-intensive industry, particularly in regions with rocky terrain. Various winemakers throughout many years faced accusations of abusive labor practices, causing scandals in the natural wine world. Those incidents sparked dialogue on fair labor practices and highlighted the interconnectedness of the industry. A brand's reputation on being more conscious does not remain a local issue, as a labor issue in a conscious brand does not remain a local issue.

Chapter 5

New Challenges and Technologies, Business and Vineyard Management

Sustainable vineyard management

Growing wine grapes can be done in a variety of ways. Among them are conventional, sustainable, organic, holistic, biodynamic, regenerative, dry farmed, irrigated, tilled, minimal tilled, and no-tilled crops. In terms of viticultural efficacy, operational efficiency, and financial success, some grape producers outperform others regardless of strategy.

Some key factors should be considered when approaching the vineyard management, namely: **timing, consistency, attention, evaluation, and progress.**

Regarding vineyard monitoring, attention is another important element. A winemaker must be able to see what is happening in the vineyard, diagnose issues as they arise, and begin working on preventative measures.(Progressive Viticulture, 2017). An essential procedure in productive vineyards is a business and operational strategy, which can include the following:

1. Business objectives
2. Environment impacts and risks
3. Vineyard management challenges (critical zones/areas)
4. Vineyard management goals
5. Vineyard management working plan (yearly operations and dates)
6. Financial plan
7. Monitoring and analysis of samples
8. Success criteria
9. Plan review and update
10. Plans for atypical events

Holistic and ecosystem management

Holistic management involves managing wholes, including people, land, and money, as a cohesive unit, with broad goals created using three components formulated in a specific order. The people first decide what kind of life they want to live and then instill their culture and values.

Next, they list the types of production that must be carried out on the land in order to maintain the desired standard of living, including food, fiber, profit, beauty, recreation, and cultural elements. Finally, they characterize and map a landscape in terms of the biological succession, mineral cycle, water cycle, and energy flow, which together make up our ecosystem.

If the current production methods are to continue, this landscape component must describe the land (or water) not as it is today but as it must be at some point in the future. Following the three-part purpose and the construction of a whole for management, we employ a "conscious" thought model that allows us to make management decisions that are ethical from an ecological, social, and economic standpoint.

Ecosystem management strives to protect or restore ecological integrity while taking into account land use policies and human demands and is comprised of a highly diverse hierarchy.

The biosphere, the largest biological unit, includes all living organisms and ecological processes. It entails evaluating vineyard characteristics, safeguarding crucial habitats, maintaining biodiversity, and advocating for the conservation of indigenous species. Agroecological concepts, organic pest control, and working with nearby communities and conservation groups are some examples of management techniques. An ecosystem management strategy recognizes that humans contribute to and have a big influence on the structures and functions of ecosystems. This method also acknowledges how much people depend on and engage with the ecological, economic, and social systems in their communities. The main objectives of an ecosystem management strategy are to:

- **Maintain ecosystem integrity**
- **Sustain regional biodiversity**

Business guidelines, marketing and sales strategies

Before **beginning a winegrowing project**, winegrowers must conduct local climate, soil, and grape variety study and make plans for them. The farmer would choose ideal property for vineyards after creating the basic plan, considering elements like sun exposure, drainage, and accessibility. It is now appropriate to begin planting, keeping in mind the need for sufficient irrigation, soil aeration, and fertilizing.

Another important factor is the **wine quality**, which besides vineyard management and fruit quality depends on technical skills and experience of the winemaker and available equipment in the winery. Winemaking continuity is crucial in determining a winery's value as a going business concern. The traditional method assumes the current management-production team will continue or be easily replaced. However, the winemaker is often missing in small winery purchases, making it difficult to replace. The acquisition value should be discounted due to the cost and risk of replacing the winemaking skill and maintaining a high reputation. Negotiation is essential in determining the value of a winery.

When there is sufficient assurance that the labor done in the vineyard and winery is safe and is being handled appropriately, the owner can concentrate on other relevant subjects such as **brand creation and identity**. Any winemaker will be greatly aided or hampered by this mistakenly straightforward operation. The brand is meant to be a true reflection of the winemaker, farm, and wines' personalities.

Consumer and market demand, product recognition, advertising, and product reach are all factors in brand building. It is one of the winery's most durable components since a strong brand may shape consumer perceptions and support continued sales. The better the reputation of the brand, the bigger the resilience compared to market fluctuations. After establishing a brand, winegrowers can create a professional website, and engage with customers through social media. Online sales even though being a minor share of the total, have been growing in the last decade. Using offline and online channels, including on-site tasting rooms, wine clubs, local retailers, restaurants, and online platforms one can explore a larger reach of audience.

New methods, products and technologies

Viticulture Innovations

- Remote sensing
- Satellite photography
- Mechanical harvesting technology
- Disease and pest control
- Drones with cameras and sensors
- Terrestrial autonomous robots
- Research and Vine breeding programs
- Nanobiotechnology

Winemaking Innovations

- Wine fermentation
- Sulphur dioxide (SO2)
- Terraced areas

Climate change adaptations for increased crop security

Heat stress, water deficits, and waterlogging are critical factors in grapevine growth and survival. High temperatures can accelerate budburst, new vegetative growth, and the emergence of inflorescences, while prolonged periods can impact carbon assimilation and sugar accumulation. Berries are also vulnerable to heat stress, resulting in berry composition and wine quality issues. Water deficits can hamper cell division, elongation, growth, and reproductive development, leading to increased sugar concentration, altered chemical composition, and sensory characteristics.

Pest and disease pressure are also significant concerns due to climate change, since pests are also vulnerable to climatic events, some like the Lobesia botrana (Reis et al., 2021)will have lesser impactful episodes. The spatial and temporal distribution of insects and pathogens is largely determined by temperature, light, and water, which control their growth and development. Regular monitoring and an adaptive preventative program are essential to address these challenges. Soil properties and dynamics significantly impact vine physiology, yield, and grape quality.

Climate change can also have a somewhat beneficial effect, as grape variety plasticity becomes increasingly relevant, new zones that previously could not be destined for viticulture are now becoming available. According to some writers, the anticipated changes show that grapevine climate suitability has been extended up to 55°N, which may signal the birth of new wine-producing regions. (Fraga et al., 2016)

Climate change adaptations for increased crop security

Given that the wine sector is predicted to be greatly impacted by climate change, it is critical to assess strategies for actively reducing greenhouse gas emissions. Fuel and power use are substantial factors, with low nitrous oxide emissions, according to Australian vineyard data. The most efficient approaches to reduce emissions are cutting back on carbon-based energy sources, altering when nitrogen fertilizer is applied, and using mulch and compost to increase soil carbon storage.(Longbottom & Petrie, 2015)
Winegrowers can take steps to boost **soil organic carbon sequestration** in addition to crop security, which can actively decrease and help reverse climate change. An investigation of the effects of organic additives on the physical, chemical, and biological characteristics of sandy vineyard soil lasted for 28 years. Crushed clipped vinewood, spent mushroom compost, and cow manure were applied annually and contrasted with unaltered treatments. In unamended plots, total organic carbon (TOC) fell by 19%; however, exogenous organic additions caused TOC to rise. In unamended plots, soil microbial biomass was minimal; however, fair levels were seen for single rates of cattle manure and spent mushroom compost, as well as moderate volumes of crushed pruned vinewood. Exogenous organic additions improved soil's ability to retain water, decreased bulk density, and raised P and K concentrations. However, high rates of organic inputs resulted in mineralized nitrogen that was greater than what the vines needed, creating a risk of N leaching.(Morlat & Chaussod, 2008)

VITISKILLS

GREEN AND DIGITAL SKILLS FOR SUSTAINABLE VITICULTURE

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